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An Innovative Approach for Multi-Exposure Image Fusion by Optimizing A Structural Similarity Index

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ABSTRACT

Multi-exposure image fusion (MEF) is considered an effective quality enhancement technique widely adopted in consumer electronics, A single captured image of a real-world scene is usually insufficient to reveal all the details due to under- or over-exposed regions. In this paper a multi-exposure image fusion(MEF) algorithm by optimising a objective quality measure namely the MEF structural similarity index (MEF-SSIM). Specifically, first construct the MEF-SSIM index by improving upon and expanding the application scope of the existing MEF-SSIM algorithm. The final high quality image has little dependence on initial image.Experimental results demonstrate the superiority of the proposed method in terms of subjective and objective evaluation.

Keywords: Multi-Exposure Image Fusion (MEF), Structural Similarity (SSIM)

I. INTRODUCTION

Images taken by ordinary digital cameras usually suffer from a lack of details in the under-exposed and over-exposed areas if the camera has a low or high exposure setting. High dynamic range (HDR) imaging solves this problem by taking multiple images at different exposure levels and merging them together. This technique has been widely used in digital camera and mobile phone devices. Generally speaking, existing HDR imaging approaches can be divided into two categories: tone mapping based methods and image fusion based methods. Multi exposure image fusion (MEF) is a cost effective technique that bridges the gap between the high dynamic range (HDR) of luminance levels in natural scenes and the low dynamic range (LDR) of standard display devices [1]. The input sequence of an MEF algorithm consists of multiple pictures of the same scene taken at different exposure levels, each of which captures partial information of the scene. The basic assumption of most existing multi-exposure fusion methods is that the scene is static during different captures. However, while fusing images taken in dynamic scenes which contain camera movement or motion objects, the methods mentioned above may produce serious distortions. To remove the impacts of camera movement, many multi exposure image alignment methods have been proposed [2].

Moreover, all existing algorithms start by pre-defining a systematic computational structure for MEF (e.g.,multi-resolution transformation and transform domain fusion followed by image reconstruction), with weak and indirect support of the validity and optimality of such a structure. In addition, most existing MEF algorithms are demonstrated using a limited number of hand-picked examples, without subjective verifications on databases that contain sufficient variations of image content or objective assessment by well-established and subject-validated quality models [3].

Unlike existing MEF methods that employ a pre-defined computational structure, we directly explore in the space of all images, searching for the image that optimizes MEFSSIMc, which is a more a model built upon MEF-SSIM. More specifically, we first construct the MEF-SSIMc model by expanding the application scope of MEF-SSIM from grayscale to color images and by better accounting for the impact of luminance changes on image quality.We then derive an analytic form of the gradient of MEF-SSIMc in the space of all images and use it to iteratively search for the optimal MEF-SSIMc image.

For example, in order to preserve color information, the relative signal strength between multiple color channels in a color space such as RGB is contained in the structural component of the proposed color patch representation. As such, preserving patch structure will also implicitly preserve color information. By contrast, existing MEF algorithms that treat RGB channels separately do not have an appropriate mechanism to enforce color preservation and thus often produce unwanted color or luminance changes.

Multi-exposure image fusion is preferred for consumer electronic applications since it does not require the HDR image construction process which increases some computing cost. Many multi-exposure image fusion methods have been proposed.

In recent' years, multi-resolution transforms have been recognized as a very useful approach to analyse the information content of images for the purpose of image fusion. The discrete wavelet transform has become a very useful tool for fusion. These methods show a better performance in spatial and spectral quality of the fused image. The notion of multi resolution analysis was initiated by Burt and Adelson who introduced a multi resolution image representation called Gauss-Laplacian pyramid. Hence, multi resolution analysis has become a very useful tool for analysing remote sensing images. Their idea is to decompose an image into a set of bandpass filtered component images, each of which represent a different band of spatial frequency. Other researchers such as Mallat further extended this idea and Meyer, who established a multi resolution analysis for continuous functions in connection with wavelet transforms. The advantage of wavelet transforms over Fourier transforms is temporal resolution that is it captures both frequency and time information.

II. RELATED WORK

Shutao Li and Xudong Kang [5] proposes a weighted sum based multi-exposure image fusion method which consists of two main steps: three image features composed of local contrast, brightness and color dissimilarity are first measured to estimate the weight maps refined by recursive filtering. Then, the fused image is constructed by weighted sum of source images. The main advantage of the proposed method lies in a recursive filter based weight map refinement step which is able to obtain accurate weight maps for image fusion. Another advantage is that a novel histogram equalization and median filter based motion detection method is proposed for fusing multi-exposure images in dynamic scenes which contain motion objects. Furthermore, the proposed method is quite fast and thus can be directly used for most consumer cameras. Experimental results demonstrate the superiority of the proposed method in terms of subjective and objective evaluation.

Zhengguo Li, **Jinghong Zheng, Zijian Zhu, and Shiqian Wu** introduce an exposure fusion scheme for differently exposed images with moving objects. The proposed scheme comprises a ghost removal algorithm in a low dynamic range domain and a selectively detail-enhanced exposure fusion algorithm. The proposed ghost removal algorithm includes a bidirectional normalization-based method for the detection of non-consistent pixels and a two-round hybrid method for the correction of non-consistent pixels. Our detail-enhanced exposure fusion algorithm includes a content adaptive bilateral filter, which extracts fine details from all the corrected images simultaneously in gradient domain. The final image is synthesized by selectively adding the extracted fine details to an intermediate image that is generated by fusing all the corrected images via an existing multi scale algorithm. The proposed exposure fusion algorithm allows fine details to be exaggerated while existing exposure fusion algorithms do not provide such an option. The proposed scheme usually out performs existing exposure fusion schemes when there are moving objects in real scenes. In addition, the proposed ghost removal algorithm is simpler than existing ghost removal algorithms and is suitable for mobile devices with limited computational resource.

Rui Shen, Irene Cheng, Jianbo Shi, and Anup Basu, A single captured image of a real-world scene is usually insufficient to reveal all the details due to under- or over exposed regions. To solve this problem, images of the same scene can be first captured under different exposure settings and then combined into a single image using image fusion techniques. In this paper, we propose a novel probabilistic model-based fusion technique for multi-exposure images. Unlike previous multi-exposure fusion methods, our method aims to achieve an optimal balance between two quality measures, i.e., local contrast and color consistency, while combining the scene details revealed under different exposures. A generalized random walks framework is proposed to calculate a globally optimal solution subject to the two quality measures by formulating the fusion problem as probability estimation. Experiments demonstrate that our algorithm generates high-quality images at low computational cost. Comparisons with a number of other techniques show that our method generates better results in most cases.

Many existing MEF algorithms follow a weighted summation framework,

$$\mathbf{y} = \sum_{k=1}^{K} w_k \mathbf{x}_k$$

Where K is the number of exposure levels in the source image sequence. $\mathbf{x}k$ represents a co-located pixel or patch in the k-th exposure image $\mathbf{X}k$, depending on whether the algorithm is a pixel-wise or patch-wise method. $\mathbf{y}$ denotes the corresponding pixel or patch in the fused image $\mathbf{Y}$. The weight wk carries the information about the perceptual importance of $\mathbf{x}k$ in the fusion process. In transform domain approaches, $\mathbf{x}k$ and $\mathbf{y}$ may also be co-located transform coefficients or a group of neighboring coefficients. Most existing algorithms differ in the computation of wk and how it may adapt over space or scale based on image content. Equation (1) has been taken for granted by a majority of MEF algorithms, but there has been very little discussion about why weighted summation is a good way of fusion and how far it is from optimality.

To overcome the misalignment problem caused by camera and object motion, several algorithms have been proposed. Zhang *et al.* [4] used gradient direction to differentiate the dominant background from the moving object. A median filter was used to filter out the moving object in [5]. Li *et al.* [6] enabled their two level detail enhancing image fusion scheme to account for dynamic scenes by explicitly detecting and correcting inconsistent pixels with respect to a chosen reference image. Qin *et al.* tackled camera and object motions in the source sequence by a patch-wise matching algorithm. The weight for each patch was computed using a random walker method [7].

III. CONCLUSION

The proposed approach consistently produces better quality fused images both qualitatively and quantitatively. Moreover, the optimization algorithm is well behaved in the sense that given any initial image, it is able to find a high quality fused image with both sharp structures and vivid color appearance. the proposed algorithm is iterative, it may not be suitable for real-time applications. An efficient non-iterative algorithm with the spirit of MEF-SSIMc in mind is highly desirable. In future work, we will explore more effective quality measures and the possibility of incorporating multi-resolution technique in the fusion process to further enhance our technique for different fusion problems. We will also explore the possibility of applying the generalized random walks framework to other image processing problem.

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